

NASA Glenn Safety Manual

CHAPTER 8 - ELECTRICAL SYSTEM SAFETY

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Table of Contents

- 8.1 Scope
- 8.2 Applicability
- 8.3 Authority
- 8.4 Responsibilities
- 8.5 Definitions
- 8.6 Codes And Standards
- 8.7 Electrical Shock
- 8.8 General Electrical Safety Considerations
- 8.9 Special High Voltage Electrical Safety Considerations
- 8.10 Equipment Safety Test and Checks
- 8.11 Experimental Equipment
- 8.12 Bibliography
- Appendix A

8.1 SCOPE

Electrical systems safety encompasses the responsibilities, regulations, and requirements that ensure a safe working environment for personnel engaged in electrical work at Glenn Research Center (GRC). This chapter sets forth minimum electrical safety guidelines and standards within the framework of GRC safety policies and constraints. It is for professional designers and craftsman; it IS NOT an instructional manual for untrained personnel. Nor is it a substitute for the detailed procedures judged necessary for the safe conduct of a specific task.

8.2 APPLICABILITY

The provisions of this chapter are applicable to all NASA employees and to all other agencies, organizations and contractor personnel who design, construct, inspect, operate, maintain or manage electrical systems within the confines of GRC at Lewis Field and at the Plum Brook Station in Sandusky.

8.3 AUTHORITY

The authority for the electrical systems safety chapter is derived from the "NASA Safety Manual", NPG 8715.3, January 2000.

8.4 RESPONSIBILITIES

Specific responsibilities of individuals or organizations tasked with establishing safety requirements for electrical systems are as follows:

8.4.1 Area Safety Committees

The Area Safety Committees conduct third-party reviews of all proposed installations, modifications, and operations in their assigned areas, to ensure that all electrical systems meet minimum design, operational, and safety standards.

8.4.2 Electrical Applications Safety Committee

The Electrical Applications Safety Committee (EASC) reviews all major electrical power systems. This committee is primarily responsible for high voltage electric power systems. It reviews novel electrical applications and advises Area and special Safety Committees concerning electrical systems safety.

The EASC issues operating Safety Permits for the GRC Lewis Field and the GRC Plum Brook Station high voltage electric power distribution systems and for the high voltage variable frequency electric power system in Building 23. This Committee reviews and permits any construction, maintenance, or repair activity that will modify a permitted system's one line diagram or that will require a non-electrical work crew to work in the vicinity of high voltage lines or equipment, both inside and outside of electric supply stations, on the GRC Lewis Field or the GRC Plum Brook Station premises.

8.4.3 Process Systems Safety Committee

The primary responsibility of the Process Systems Safety Committee is to ensure that the central process systems are designed and operated safely. The Committee conducts third-party reviews of all proposed installations, modifications, and operations that could affect systems specifically assigned to this committee, to ensure that all electrical systems meet minimum design, operational, and safety standards.

8.4.4 Supervisory Personnel

Supervisory personnel are responsible for ensuring that the requirements of this chapter are adhered to in the design, construction, modification, operation, and maintenance of electrical systems.

Supervisory personnel are responsible for ensuring that employees are trained in safety related work practices, safety procedures, and other personnel safety requirements that pertain to their respective job assignments. Employees shall not be permitted to work in an area where they are likely to encounter electrical hazards unless they have been trained to recognize and avoid the electrical hazards to which they will be exposed

8.5 DEFINITIONS

Following are some key definitions related to electrical safety. Many additional related definitions are contained within referenced documents such as the National Electrical Code (NEC) and the National Electrical Safety Code (NESC).

- a. Electric Supply Equipment: Equipment that produces, modifies, regulates, controls, or safeguards a supply of electric energy.
- b. Electric Supply Station: Any building, room or separate space within which electric supply equipment is located and the interior of which is accessible, as a rule, only to qualified persons. This includes substation, transformer, storage battery and switchgear rooms or enclosures, but does not include facilities such as pad-mounted equipment and installations in manholes and vaults.
- c. Enclosure: The case or housing of apparatus, or the fence or walls surrounding an installation to prevent personnel from accidentally contacting energized parts or to protect the equipment from physical damage.
- d. Guarded: Covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers, casings, barriers, rails, screens, mats, or platforms to remove the likelihood of approach or contact by persons or objects to a point of danger.
- e. Qualified Person: One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training on the hazards involved.
- f. Voltage (of a circuit): The greatest root-mean-square (effective) difference of potential between any two conductors of the circuit concerned.
- g. Voltage (nominal): A value assigned to a circuit or system for the purpose of conveniently designating its voltage class (e.g. 208Y/120 volts, 2400 volts, 34,500 volts). The operating voltage of the system may vary above or below this value within a range that permits satisfactory operation of equipment.
- h. Voltage, High: Electric power system and equipment operating at 601 volts nominal and above.
- i. Voltage, Low: Electric power system and equipment operating at 600 volts nominal or less.

8.6 CODES AND STANDARDS

The following codes and standards relate to the safe design, construction, operation, and maintenance of electric power systems. These codes and standards establish minimum safety requirements. Electric power systems at the GRC Lewis Field and the GRC Plum Brook Station shall meet or exceed the requirements of these documents.

8.6.1 "National Electrical Code" (NEC)

The NEC (National Fire Protection Association (NFPA)-70) covers electrical conductors and equipment installed within or on public and private buildings and other premises. This code is the primary code covering design of electrical power systems. This

document also covers electrical requirements for locations where there is a potential for fire and explosion due to flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings.

8.6.2 "National Electrical Safety Code" (NESC)

The NESC (Institute of Electrical and Electronics Engineers (IEEE) and American National Standard (ANSI) - C2) covers basic provisions for safeguarding persons from hazards arising from the installation, operation, or maintenance of (1) conductors and equipment in electric supply stations, and (2) overhead and underground electric supply and communication lines. It also includes work rules for the construction, maintenance, and operation of electric supply and communication lines and equipment.

8.6.3 "Occupational Safety and Health Act" (OSHA)

OSHA (Public Law 91-596) covers conditions, practices, or operations to ensure safe and healthful work places.

8.6.4 "NASA Safety Manual", NPG 8715.3

This document is the central Agency document containing procedures and guidelines that define the NASA Safety Program.

8.7 ELECTRICAL SHOCK

8.7.1 Hazards

Some persons who handle electrical equipment mistakenly believe that their tolerance to electric shock is related to their ability to withstand the pain of the shock. Actually, the lethal incidence is a function of the amount and duration of current passing through the chest. Furthermore, a possibly lethal current is only marginally higher than one ranked just painful and well within the range of industrial low voltage power systems.

It is current, not voltage that heats a wire, and it is current that causes physiological damage to humans. The following table shows effects of various 60-hertz currents on an average person. This data is from "Figure 6.4.3-1" of NASA-STD-3000, "Man Systems Integration Requirements", November 1986.

Current Physiological Reaction

<1 mA	None
1 mA	Perception threshold
1-3 mA	Mild sensation
3-10 mA	Painful sensation
10 mA	Paralysis threshold of arms
30 mA	Respiratory paralysis
75 mA	Fibrillation threshold (0.5%)
250 mA	Fibrillation threshold (99.5%)
4 A	Heart paralysis threshold
>5A	Tissue burning

As the magnitude of the current increases, statistically the current is more dangerous as a cause of burns than as a cause of heart failure. This is most likely due to the shorter exposure time. At very high voltages (above 2,300 volts), burns may not be severe since the victim initiates an arc that retracts (by reflex) his attempted grasp. In summary, the duration as well as the level of current affects humans. When contact is made in such a manner that the contacting part is retracted (e.g., a light finger touch during which the strong muscular contractions of the arm pull the fingers away), the shock is much less dangerous than one of the same current level incurred by "freezing" to the contact with a full hand grasp.

8.7.2 Emergency First Aid and Resuscitation Training

Personnel who work with electrical equipment should be qualified in emergency first aid procedures and cardiopulmonary resuscitation (CPR).

8.8 GENERAL ELECTRICAL SAFETY CONSIDERATIONS

This section presents GRC policies for work done on or near electrical power systems. The Low Voltage Electrical Power Systems Manager manages low voltage systems. The High Voltage Electrical Power Systems Manager manages high voltage systems. The appropriate electrical systems manager shall approve exceptions to these policies. The power systems managers are members of the Facilities and Test Engineering Division (FTED). Also see section 8.9 for special high voltage safety considerations.

8.8.1 Configuration Control

GRC has placed certain electrical power systems, including their control and protective systems, under configuration control as established by the provisions of LeR-P7500.004 "Configuration Management" procedure of FTED. Systems under configuration control are:

- a. High voltage electric power distribution systems
- b. Low voltage electric power distributions systems
- c. Variable Frequency Power System (Building 23)
- d. Electrical power systems associated with major research facilities

See paragraph 8.9.1 for specific high voltage considerations.

8.8.2 Low Voltage Electric Power System Operating Instructions (LVEPS-OI-xx)

The GRC Low Voltage Electrical Power Systems Manager periodically issues numbered operating instructions applicable to low voltage systems. All personnel responsible for design, operation, maintenance, construction or repair of such systems shall become familiar with and follow these instructions. Also see paragraph 8.9.2.

8.8.3 Electrical Isolation

GRC will not permit work on energized electrical systems. Exceptions are provided for:

- a. Probing high or low voltage apparatus to verify circuit conditions using test equipment and Personal Protective Equipment appropriate to the situation; and
- b. Probing and testing experimental equipment operating at very low voltages (see par. 8.11.2 (b)).

A GRC safety committee may approve other exceptions to this policy after careful review of the situation and hazards involved. Such decisions shall be documented. When permission is granted to work on energized equipment, only tools designed and rated for the voltage level of the system voltage shall be used. Only devices designed for voltage testing and rated for the nominal voltage of the circuit under test shall be used to make voltage checks. Each test voltage indicator shall be verified before and after use by using the hot-dead-hot technique. Only qualified persons who have been trained to work safely with test instruments and equipment on energized circuits shall be permitted to perform such tests.

To isolate low voltage electrical power apparatus, GRC requires a minimum of one electrical open. Also see paragraph 8.9.5 concerning work on or near high voltage facilities and paragraph 8.8.4 detailing Lockout/Tagout Procedures, including the Area Clearance Process and the Local Outage Process. All scheduled switching, isolation or a

qualified switch person shall accomplish lockout of low voltage distribution apparatus after approval of an "Area Clearance" form. Particular effort shall be made to ensure that all potential power sources, including PT's, are disconnected to preclude back feed of power to the isolated site.

All scheduled switching, isolation, locking out, tagging out or grounding of any part of high voltage electrical an Electrical Equipment Switching Order shall govern power systems. Particular effort shall be made to ensure that all potential power sources, including PT's, are disconnected to preclude back feed of power to the isolated site. An Electrical Equipment Switching Order shall govern the restoration of power to isolated systems or equipment. Such orders shall be prepared by the Electric Power Dispatcher at the GRC Lewis Field, or by the Responsible Engineer at the GRC Plum Brook Station. All switching procedures shall comply with the "National Electrical Safety Code," ANSI C-2, Part 4. Each switch person shall be a Qualified Operator for the specific electrical power system, shall have a copy of the written switching procedure, and shall sign the written switching procedure, attesting to completion of each step of the procedure as it is completed

8.8.4 Lockout/Tagout Procedures

Lockout/Tagout procedures shall be followed whenever work is being performed on a system or piece of equipment where operation of switches, valves, or similar devices could result in injury to personnel or damage to equipment. Lockout/Tagout procedures are detailed in the [GRC Safety Manual \(GSM\), Chapter 9](#).

Electrical safety tags give visual notice of work being performed on or near electrical power apparatus. The safety and welfare of work crews depend on the diligent observance of these tags.

INTENDED OR UNINTENDED VIOLATION OF SUCH WARNINGS OR UNAUTHORIZED REMOVAL OF THESE ELECTRICAL SAFETY TAGS SHALL BE REASON FOR DISCIPLINARY ACTION.

Whenever energized metal-enclosed electric supply apparatus (including high or low voltage, metal-enclosed switchgear, unit substations, panel boards, and switchboards that normally isolate the public from electrically energized components) are opened, special precautions shall be taken. For low voltage power apparatus, suitable insulated barriers shall be placed over the exposed energized parts and warning sign(s) shall be placed. For high voltage apparatus, a safe exclusion area shall be roped off, suitable high voltage warning sign(s) shall be placed, and a NASA designated GRC high voltage safety person shall be in attendance. No unauthorized personnel shall be permitted to enter the roped-off area without permission of the NASA designated GRC high voltage safety person. The NASA designated GRC high voltage safety person shall confirm that all personnel within the roped-off area are aware of exposed electrically energized components. When the NASA designated GRC high voltage safety person leaves the area, either a new GRC

high voltage safety person shall be designated and in attendance or the opened facilities shall be closed and secured (i.e., locked if possible).

FAILURE TO OBSERVE THE REQUIREMENTS OF THIS PARAGRAPH SHALL BE REASON FOR DISCIPLINARY ACTION.

8.8.5 Consider All Electrical Systems Energized

All electrical systems shall be considered energized until verified to be de-energized and grounded. Verification that low voltage apparatus is de-energized shall be made using a suitable voltage test device. Initial verification that high voltage apparatus is de-energized shall be made with a tic tracer or audible voltage detector by using the hot-dead-hot technique. Subsequent verification may be made by observing the open position of isolating breakers, switches, and links in sectionalizing boxes, or by observing the personnel safety grounds installed at the work site.

8.8.6 Buddy System

The "buddy" system (a second person directly observing the operation) shall be applicable to all aspects of electrical work on or near unguarded electrical apparatus energized at 50 volts or more, including field investigations supporting design activities, and all construction, operation, and maintenance activities. See Section 8.9.3 for special requirements for entering areas containing high voltage equipment or circuits. See "The GRC Buddy System", [Glenn Safety Manual Chapter 22](#).

8.8.7 Work In Confined Space

Many electrical systems are contained within areas identified as confined spaces. Entry into confined spaces is governed by procedures detailed in the Glenn Safety Manual, [Chapter 16](#). In addition, if high voltage cables or equipment are contained within the space, a Safety Permit issued by the Electrical Applications Safety Committee may be required.

Specific requirements for entering confined spaces containing high voltage electric supply equipment or cables are described in HVEPS-OI-004.

8.8.8 Conduit Fish Wire

When fishing a tape or wire through a conduit or duct, suitable protective barriers shall be placed and personnel shall be stationed so as to prevent the free ends of the tape or wire from contacting energized equipment.

8.8.9 Validation of Operating Equipment

New electrical equipment, repaired electrical equipment where the repair involved the insulation system, and electrical equipment that has not been energized for an extended

period of time shall be tested to ensure that the equipment dielectric strength is at a safe level prior to energizing the equipment. The appropriate High or Low Voltage Electrical Power Systems Manager should be consulted for specific testing requirements for a particular piece of equipment. In general, power system equipment shall be tested for minimum values of 1 megohm or 1 megohm per 1000 volts of operating voltage, whichever is greater. A dc "megger" appropriate to the circuit voltage shall be used to obtain the readings. Instructions provided by the megger manufacturer, including calculations to correct readings for temperature and humidity conditions, shall be followed in the use of the megger instrument. If lesser values of insulation resistance are obtained, the responsible engineering group shall make a risk assessment before energizing the equipment. Reasons for energizing equipment with insulation resistance below accepted minimum values should be documented.

8.8.10 Color Coding of Indicating Lights and Electronic Control Screens

Color caps on indicating lights designating the condition or position of the contacts on circuit breakers or switches shall conform to the following:

- a. Contacts closed - **red**
- b. Contacts open - **green**
- c. Contacts automatically tripped open - **amber** (if furnished) or **white**

Color caps on indicating lights designating the position of a valve that allows or blocks flow shall conform to the following:

- a. Allows flow - **green**
- b. Blocks flow - **red**

Colors used on electronic screens designating condition or position of the contacts on circuit breakers or switches shall conform to the following:

- a. Contacts closed - **red**
- b. Contacts open - **green**
- c. Contacts automatically tripped open - **white** (if furnished)

Colors used on electronic screens designating the position of a valve that allows or blocks flow shall conform to the following:

- a. Allows flow - **white**
- b. Blocks flow - **cyan (light blue)**

These required designations may be waived by the Glenn Safety Office (GSO) if, on the basis of prior usage in a facility, the GSO deems it safer to use other designations. This special ruling shall require written notification and approval from the GSO.

8.8.11 Separately Derived Electric Power Systems

Separately derived electric power systems, such as those systems whose power is derived from generators, transformers, converter windings, photovoltaics or battery-powered systems, present unusual safety considerations. Design, installation, operation, and maintenance of such systems shall conform to the "National Electrical Code" (NFPA 70). Designs for such systems shall be reviewed and approved by the appropriate GRC High or Low Voltage Electrical Power Systems Manager for systems to be installed at the GRC Lewis Field site or by the Plum Brook Management Office for systems to be installed at the GRC Plum Brook Station.

8.8.12 Battery Systems

Vented batteries and battery cells, regardless of electrode type, contain dangerous electrolytes that are subject to spillage. Overcharging or too rapid charging can cause boiling and spewing of electrolytes and production of explosive gases. The following precautions shall be observed in handling these devices:

- a. Face shields, rubber gloves, and protective rubber aprons shall be available near the batteries and shall be used whenever batteries or cells are being handled, filled, or charged.
- b. An eye wash station shall be located near each battery bank.
- c. Ample water shall be available to flood any electrolyte spill occurring in battery operations.
- d. No smoking, open flames, or sparking devices shall be permitted in a battery area.
- e. Provisions shall be made for sufficient diffusion and ventilation of gases from the battery to prevent the accumulation of an explosive mixture.
- f. GSO shall review new battery installations.

If battery electrolyte should come into contact with skin or clothing, immediately treat it with water or a weak neutralizing solution.

Electrolyte in the eyes, however, is a very dangerous situation; immediately flush the eyes with profuse amounts of water then **SEEK MEDICAL ATTENTION**.

8.8.13 Instrument Transformers

The following precautions shall be observed in handling instrument transformers.

- a. Current transformer cases and secondaries shall be grounded. Where more than one set of current transformers are connected electrically, a ground point shall be selected that provides grounding for the network.
- b. Secondaries of current transformers **shall never** be opened while the primary circuit is energized.
- c. The case and one wire of the low voltage side of potential transformers shall always be grounded before energizing the transformer.

8.8.14 Valve Disconnect Switch

Any valve that could expose personnel to high pressures, large vacuum systems, or dangerous gases or fluids when equipment is energized, shall have a disconnect switch adjacent to the valve. The disconnect switch shall open each ungrounded power lead and shall open the power to the control circuit. The disconnect switch shall be capable of being padlocked in the open position.

8.8.15 Hazardous (Classified) Locations

Many areas at the GRC Lewis Field site and the GRC Plum Brook Station are classified or need to be classified as hazardous locations where fire or explosion hazards may exist due to the presence of flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings. Facilities and test rigs employing or storing such hazardous items shall obtain formal approval of area classification(s) from the GSO. Guidance for classifying areas is contained in various NFPA publications. Requirements for electrical and electronic equipment and wiring for all voltages in such classified locations is covered in NEC Articles 500 through 516. NEC paragraph 500.5(A) FPN reminds us that "Through the exercise of ingenuity in the layout of electrical installations for hazardous (classified) locations, it is frequently possible to locate much of the equipment in a reduced level of classification or in an unclassified location and, thus, to reduce the amount of special equipment required." Responsible personnel shall involve the GSO early in evaluations of use of hazardous materials and the need for classified electrical equipment.

All hazardous (classified) locations shall have suitable and prominent warning signs posted to clearly identify that the area is a classified location, what the area classification is and the organization responsible for the area. Signs shall be framed and securely mounted. Signs shall be 8.5 inches by 11 inches or larger. See Appendix A at the end of this Chapter for an example of a hazardous (classified) area warning sign for a simple, single classification area. More complex situations may require posting additional information, such as a framed sketch depicting multiple classifications within the area, along with the warning sign.

No construction or change to operating procedures shall be allowed within a hazardous (classified) area without a review conducted by the Area Safety Committee that documents the rationale leading to approval of the construction or change to operating procedures.

The organizational element responsible for a hazardous (classified) area shall maintain a file relating to the area. Such files shall contain the document(s) identifying area classifications and the GSO approval. Supporting documents such as calculations, preliminary and final hazard analyses and related meeting minutes shall be included in the file.

8.8.16 Capacitors

Design and installation of all capacitors, except surge capacitors or capacitors furnished as NEC Article 460 governs a component part of other apparatus. Before employees work on capacitors, the capacitors shall be disconnected from the energizing source, short-circuited, and grounded. Any line to which capacitors are connected shall be short-circuited and grounded before it is considered de-energized. Since capacitor units may be connected in series-parallel configurations, each unit shall be shorted between all insulated terminals and the capacitor tank before handling. Racks for capacitors shall be grounded. Any internal resistor shall not be depended upon to discharge capacitors. Also see paragraph 8.11.3 for special requirements for high voltage capacitor banks used as part of experimental equipment.

8.9 SPECIAL HIGH VOLTAGE ELECTRICAL SAFETY CONSIDERATIONS

8.9.1 Connections to High Voltage Supply

All connections or modifications to high voltage electric power systems require special considerations. The Electrical Application Safety Committee reviews and permits all such changes. High voltage electric power distribution systems are under configuration control, and change control procedures established by FTED apply to all modifications and additions to the systems. In addition, major facilities incorporating high voltage systems and equipment are under configuration control by the responsible operating organizations. Each of these organizations has unique configuration control requirements covering changes to their controlled systems. At Plum Brook Station, the Plum Brook Management Office maintains configuration control. In general, prior to additions or modifications to such systems, formal engineering documentation, appropriate safety review, and final approval by the organization with configuration control responsibility are required.

8.9.2 High Voltage Electric Power System Operating Instructions (HVEPS-OI-xx)

The GRC High Voltage Electrical Power Systems Manager periodically issues numbered operating instructions applicable to high voltage systems. All personnel associated with the design, operation, maintenance, construction or repair of such systems shall become familiar with and follow these instructions. Also see paragraph 8.8.2.

8.9.3 Entry Into Electric Supply Stations

Entry into electric supply stations by other than the authorized maintenance personnel requires the designation of a GRC high voltage safety person to monitor and control the activity (see par. 8.9.4). All such entries shall be coordinated through the Electric Power Dispatcher at Lewis Field and through the Plum Brook Management Office at Plum Brook Station. The NASA designated GRC high voltage safety person shall notify the Electric Power Dispatcher upon entering and leaving the station. Such notification shall include the purpose of the activity.

ALL UNAUTHORIZED ENTRIES INTO ELECTRIC SUPPLY STATIONS, REGARDLESS OF WHETHER THE STATION IS ATTENDED, UNATTENDED, LOCKED, OR UNLOCKED, SHALL BE REASON FOR DISCIPLINARY ACTION.

8.9.4 NASA designated GRC High Voltage Safety Person

At GRC Lewis Field, the NASA designated GRC high voltage safety person who monitors and controls entry into electric supply stations, power manholes, cable tunnels or rooms, and transformer vaults is designated by the high voltage maintenance contractor from the list of Qualified Operators approved by the COTR/ACOTR and as incorporated into the approved GRC Electrical Applications Safety Permit for operation of the high voltage system. For other areas containing high voltage equipment at GRC Lewis Field, the NASA designated GRC high voltage safety person is appointed by the operations contractor or test supervisor for that area, with the concurrence from their respective COTR/ACOTR and as incorporated into the approved GRC Safety Permit for operation of the high voltage system (i.e. Building 23 Variable Frequency Power System). At the GRC Plum Brook Station, the NASA designated GRC high voltage safety person is designated by the Technical Services Group supervisor. The specific duties and requirements for the NASA designated GRC high voltage safety person in the high voltage electric power systems are described in HVEPS-OI-012.

8.9.5 Work On or Near High Voltage Facilities

On high voltage facilities.--The general requirement for working on high voltage electric supply equipment or lines shall be to provide two open breaks in series on all electrical phases between the work site and each energy source, including back feeds, and one open break between the work site and potential transformers. Visible protective safety grounds shall be provided either on both sides of the work site or at the work site.

This general requirement, called "two opens," shall be the Center's objective and shall be met in the majority of Electrical Equipment Switching Orders to isolate high voltage electric supply equipment or lines. The Electrical Power Dispatcher shall approve exceptions to this general requirement.

When more than one work site exists on isolated high voltage electric supply equipment or lines, such as along an overhead 7,200 volt or 34,500 volt distribution lines, visible protective safety grounds shall be provided at both ends of the distribution line and at each work site.

Near high voltage facilities.--When work is performed near high voltage electric supply equipment or lines utilizing air-insulated configurations, such high voltage supply equipment or lines shall be isolated and grounded in accordance with paragraph 8.8.3 or the high voltage facilities shall have suitable guards installed which preclude encroachment into minimum safe working clearances from the energized facilities.

When work is performed near insulated high voltage electrical cables and associated cable apparatus, cables and associated cable apparatus are not required to be de-energized. For such cases when cables or cable apparatus are requested to be de-energized, one electrical break is required. Utilization of protective safety grounds is optional

Specific electrical isolation and grounding requirements for the high voltage power systems are presented in HVEPS-OI-011, "Work On or Near High Voltage Electrical Systems." Minimum safe working distances from air-insulated high voltage apparatus are shown in HVEPS-OI-012.

8.9.6 High Voltage Switching

All electrical switching required to isolate electrical circuits or equipment is to be performed only by personnel who have been listed on an approved Qualified Operator's List ([NASA Form C-580](#)) as certified switch person for the specific circuits or equipment

The following precautions must be observed:

- a. Disconnecting poles (hot sticks) and rubber gloves shall be used when operating high voltage, hook-stick-operated disconnecting switches having open circuit voltages. The following table lists the minimum pole length for various voltages:

Voltage	Minimum length of disconnect pole, ft
601 to 7,500	4
7,501 to 50,000	8
50,001 to 73,000	12
73,001 to 138,000	16

- b. Rubber gloves with leather protectors shall be worn when operating any manually operated, mechanically connected, remotely controlled air break switch where the voltage exceeds 600 volts.
- c. No work shall be done on circuits or equipment isolated from power sources by oil switches alone.
- d. A switch person operating any switch used for maintenance or for isolation of circuits above 600 volts shall be accompanied by a NASA designated GRC high voltage safety person who shall stand at a safe distance and be prepared to take any necessary steps in event of an emergency.

8.9.7 Cutting High Voltage Cables

Cutting high voltage cables when neither end of the cable is visible from the location of the cut presents unique safety considerations. The procedure to identify and cut high voltage electric cables is governed by HVEPS-OI-009.

8.9.8 Lifting or Construction Equipment, Vehicles or Personnel Near Exposed Energized Electrical Parts

Distance - Personnel working near and/or using hoisting, lifting, or other construction equipment or vehicles near air insulated energized electrical lines or exposed terminals of electrical apparatus are subject to the minimum safe working distances established in HVEPS-OI-012. Construction equipment shall be separated far enough from such lines and apparatus so that equipment failure would not result in the construction equipment approaching energized electrical facilities closer than the established minimum safe work distance.

Grounding - All equipment shall be effectively grounded (to ensure proper fault protection) when being moved or operated in close proximity to energized lines or electrical apparatus. Consideration shall be given to grounding the load, particularly if insulated lifting straps are in use. All such operations shall have a dedicated observer (without any other duties) to warn equipment operators of potentially hazardous situations and/or movements.

8.9.9 Fuses

Fuses on energized circuits above 34,500 volts shall not be removed. Procedures to be used when removing or replacing fuses on unloaded energized circuits shall conform to the following:

- a. On circuits rated 50 to 600 volts, insulating fuse tongs or extractors shall be used.
- b. On circuits rated 601 to 1,000 volts, lineman's type rubber gloves with leather protectors and either insulated fuse tongs or extractors shall be used.
- c. On circuits rated 1,001 to 34,500 volts, lineman's type rubber gloves with leather protectors, a protective Nomex suit, and insulated high-voltage sticks or tongs shall be used.

8.9.10 Rubber Insulating Gloves

Lineman's type rubber gloves shall be tested at least semi-annually for the pertinent circuit voltage in accordance with ASTM D120, "Standard Specification for Rubber Insulating Gloves." In addition, a standard air test shall be made immediately before each use. Leather protectors shall always be worn over lineman's rubber gloves.

All qualified switch persons shall have a personal pair of rubber insulating gloves, protective leather gloves, and a glove bag. In addition, two pairs of insulating gloves, protective leather gloves, and a glove bag shall be stored at each high voltage substation and at each major research facility control room.

Personal gloves shall be constructed of three-ply insulating rubber sheet. The outer ply shall be constructed of stretched black rubber and the inner ply shall be constructed of a non-black (preferably yellow) heavy rubber sheet. With this construction a minute puncture or slit of the outer stretched black rubber sheet would immediately pull apart, thereby revealing the inner rubber sheet. Whenever the inner rubber sheet is visible, the pair of gloves shall be discarded.

8.9.11 Hard Hats

All personnel entering high voltage electric supply stations, power manholes, electrical cable tunnels, electrical cable rooms, or transformer vaults shall wear a Class-2 hard hat conforming to 29 CFR 1910.135.

8.9.12 Safety Shoes

All personnel who regularly enter high voltage electrical supply stations, power manholes, electrical cable tunnels, electrical cable rooms, or transformer vaults shall wear safety shoes meeting 29 CFR 1910.132.

8.9.13 Protective Suits

Personnel shall wear protective safety suits made from Nomex or other suitable flash-proof material when:

- a. Removing or installing fuses in energized high voltage circuits;
- b. Performing LO/TO on 13.8KV switchgear circuit breakers if any breaker in lineup is closed.
- c. Performing LO/TO on 34.5KV switchgear circuit breakers if any breaker in lineup is closed.

8.9.14 Eye Protection

Safety glasses, goggles, or face shields shall be worn by an individual in any area or during any work where there is a reasonable probability of eye injury, such as when making electrical measurements on energized electrical circuits. Eye and face protection shall meet or exceed ANSI Z87.1 standard "Occupational and Educational Eye and Face Protection Practice". See Chapter 15.

8.9.15 Ladders

Only fiberglass or wood ladders shall be used near electrical hazards. Metal ladders should be marked with signs or decals reading **"CAUTION-DO NOT USE NEAR ELECTRICAL EQUIPMENT."**

8.9.16 Hot Sticks

All hot sticks used at GRC Lewis Field and the GRC Plum Brook Station shall be made of fiberglass. Field care, handling, and storage shall be per ANSI/IEEE Standard 516, Section 4.

8.9.17 Work in Electric Supply Stations or Near Exposed Lines or Apparatus

For all work within energized high voltage electric supply stations or in the vicinity of exposed energized high voltage lines or apparatus:

- a. Each contractor shall abide by all applicable OSHA, NEC, NESC, and GRC safety rules and regulations. GRC Safety Documents are incorporated into the contractor's contract by reference, normally in Section H of the contract, and as such, have the same force and effect as if they were given in full text. The full

text of the GRC safety documents shall be provided to the contractor upon the contractor's request of the Contracting Officer.

- b. Each contractor shall appoint an individual to be responsible for the electrical safety of each of the contractor work teams. Before starting the work, the contractor shall provide a document to the Government establishing that the appointed safety supervisor(s) is(are) qualified and knowledgeable in all required safety regulations. The contractor's safety person(s) shall ensure that each work area and a safe zone beyond the work area have been de-energized and made safe before permitting a team to work in the energized electric supply station. GRC high voltage safety persons shall check to be sure that the desired circuits have been de-energized and properly grounded. Note: This requirement is not to be confused with the NASA designated GRC high voltage safety person required by Section 8.9.3.
- c. Each contractor shall install all barriers and rope guards deemed necessary to clearly define the work area and sufficient to protect the workers from inadvertently moving out of the safe work area. Work area separation from exposed energized lines and apparatus shall be as established in HVEPS-OI-012.

8.10 EQUIPMENT SAFETY TEST AND CHECKS

8.10.1 Tests to be Performed Prior to Initial Energization

Initial energization of all new electrical equipment shall be done only in the presence of the appropriate Government representative. Before the initial energization, the following tests must be done:

- a. All power feeder circuit breakers shall be checked for proper adjustments in accordance with the manufacturer's instructions. (Molded-case circuit breakers without solid state trip devices are excluded from this requirement.)
- b. All protective relays and other such devices shall be tested to be sure that they can operate in the range required. Where possible, tests shall include loading in at the current transformer secondaries to validate the circuitry as well as the device.
- c. All wiring shall be checked for conformity to the design and to functional requirements.
- d. All motors, cables, and switchgear shall be tested by the cognizant engineering group, in accordance with industry standards and manufacturer's recommendations, at voltage levels approved for the specific type of equipment. The following industry standards shall apply.

Equipment	Standard
Motors	ANSI/IEEE
Cables	AEIC
--Paper insulated	AEIC
--Rubber, ethylene, propylene rubber, cross-linked, polyethylene insulated	ICEA
Switches	ANSI/IEEE

8.10.2 Protective System Checks

Protective relay settings shall be coordinated to provide selective tripping. The High Voltage Electrical Power Systems Manager shall maintain a listing of the required settings and the frequency of periodic testing of all protective relays in use.

All high voltage electrical power system protective relays at GRC Lewis Field and GRC Plum Brook Station shall be checked and calibrated on a triennial basis. Every reasonable effort shall be made to perform an end-to-end test of the relay circuitry in the process of this check, including verification of the integrity of grounds, grounding cables, grounding resistors and grounding transformers.

8.10.3 Circuit-Interrupting Devices

All circuit-interrupting devices shall be rated to interrupt the maximum short circuit current that can be supplied by the power system at the point of application of the device.

Whenever a proposal is made to add circuit-interrupting devices to the system and whenever large loads are added or major system changes are made, the responsible engineering organization shall make system short-circuit studies to establish the circuit-interrupting duty requirements. All such studies shall be reviewed and approved by the cognizant electrical system manager.

After any operation in which a circuit breaker opens under short circuit or fault conditions, the circuit breaker shall be inspected and checked immediately to ensure suitability for reuse. All inspections and checks shall be performed following GRC Lockout/Tagout procedures and guidance contained in High Voltage and Low Voltage Electrical Power System Operating Instructions. Work on high voltage devices shall follow directions from the Electric Power Dispatcher. Inspections and checks of molded case circuit breakers shall be limited to visual inspection and a contact resistance (micro ohm) test of each pole with maximum acceptable resistance levels as established by the device manufacturer. Inspections and checks of all other circuit breakers, both low and high voltage, shall consist of: a) Visual inspection of the main contacts where the insulating medium will not be compromised by the inspection; b) An insulation (meggar) test; and c) A contact resistance (micro ohm) test. Acceptable insulation test values shall be a minimum of one megohm or one megohm per 1000 volts of operating voltage, whichever is greater. Acceptable test values of contact resistance shall be as established by the device manufacturer. If the above inspection and checks are complete and the circuit breaker appears to be within normal operating parameters, prove mechanical functionality by cycling the breaker in the test or isolated position. If the breaker fails any of the above inspections or checks, it shall not be put back into operation. When a trip occurs on breakers above 600 volts, the trouble-shooting process shall verify the settings of all breakers between the fault and the breaker that tripped. (Molded-case

circuit breakers without solid state trip devices are excluded from the requirement to verify trip settings).

To ensure satisfactory mechanical operation, all circuit breakers rated 34.5 kilovolts and above shall be operated at least once every 18 months, with the exception of those installed for 15 years or more, which shall be operated annually.

8.10.4 High-Voltage Insulation Testing

High-voltage test levels and procedures for all operating equipment shall be verified with the High Voltage Electrical Power Systems Manager to ensure that the test voltage selected and/or procedure used is based on evaluations of the type and condition of insulation, age, damage, equipment history, and desired service, as recommended in ANSI/IEEE 95, "Insulation Testing of Large AC Rotating Machinery with High Direct Voltage."

High-voltage dielectric testing shall be performed in the presence of a NASA designated GRC high voltage safety person. Isolation, tagging, area securing, and grounding procedures as required shall precede testing. During testing, all safety precautions listed in ANSI/IEEE 95, Section 6, Paragraph 6.9 shall be followed.

8.11 EXPERIMENTAL EQUIPMENT

8.11.1 Safety Responsibility

Experimental electrical or electro-mechanical equipment that is under development, and therefore subject to frequent modifications, can present a particular hazard to personnel. The operating and emergency procedures and attendant hazards may change from day to day. The project manager is responsible for the safety of personnel and equipment associated with the development of experimental apparatus. A responsible member of the team shall perform and document periodic assessment of project/equipment hazards. These assessments shall be used to establish correct working procedures, to identify need for and implement use of appropriate personal protective equipment, and to establish proper emergency procedures. Particular emphasis shall be placed on de-energization of the equipment.

8.11.2 Experimental, Developmental or Flight Level Electrical/Electronic Equipment

Following are additional guidelines for working on or near energized electrical experimental, developmental or flight level electrical/electronic equipment:

- a. A responsible member of the research and development team such as the Project Engineer shall establish correct working procedures as well as proper precautions, warnings, emergency procedures and some approved operators list. Safety should

be a recurring topic of discussion during project team meetings. Emphasis should be placed on establishing and familiarizing project personnel with emergency procedures to de-energize the equipment. New project personnel should be apprised of unusual shock hazards associated with the equipment.

- b. Electric shock can be experienced under certain conditions when working with voltages as low as 15 volts rms. The level at which exposed energized parts become dangerous is considered much lower for wet conditions, wet contact or for personnel with physical limitations such as an installed heart pacemaker. High leakage current ($>.5$ ma) could be indicative of an unsafe condition or shock hazard. Use of ground fault interrupting circuitry is encouraged. See Par. 8.7.
- c. As a minimum, guards shall be provided around exposed connections energized above 50 volts rms per the National Electrical Code.
- d. Project personnel shall not work alone on energized electrical equipment with dangerous voltage levels (see Par. 8.8.5 and Chapter 22).
- e. After deenergizing, a required minimum discharge time should be observed and/or grounding probe(s) should be utilized to discharge circuits prior to physical contact or circuit modifications to ensure that no residual or hazardous voltages remain.
- f. Where reasonable and possible, fail safe and/or current limiting circuits should be incorporated in equipment to minimize effects of personnel exposure to hazardous electric shock energy.
- g. Temporary wiring utilized should be rated for the environment and use and should be routed in a reasonably neat manner and should not pose unreasonable additional hazards.
- h. Periodic hazard assessment of project/equipment hazards and identification of appropriate Personal Protective Equipment shall be conducted. Faulty equipment, frayed cords or faulty grounding conditions shall be repaired or eliminated.
- i. Conductive articles of jewelry and clothing such as watch bands, bracelets, rings, key chains, necklaces, metalized aprons, cloth with conductive thread, or metal headgear shall not be worn where they present an electrical contact hazard with exposed energized parts unless such articles are rendered nonconductive by covering, wrapping, or other insulating means.
- j. Equipment with power circuits which utilize instrument/metering type current or potential transformers, or large capacitive or inductive elements could be extremely dangerous. These electrical apparatus pose a unique set of shock hazards and should be worked with in an energized circuit only after careful considerations of consequences such as resonances or extreme currents or voltages .

8.11.3 Experimental Equipment Utilizing High Voltage Capacitor Banks

Test personnel conducting experiments in which capacitor banks with voltages above 600 volts are employed shall have total knowledge of the experiment, the circuit, and the component layout; such personnel shall be fully trained in the operating and safety procedures to be used at that facility, including procedures to be used in the event of equipment failure. General guidance for use of capacitors on power circuits is contained

in NEC Article 460 and paragraph 8.8.19. Additional precautions and procedures are as follows:

- a. Each high voltage test area shall be enclosed and protected by using gates and interlocks on the test controls. Since capacitors and related high voltage component faults are a source of hazardous shrapnel, these components shall be isolated in a manner that precludes personnel injury or facility-related hazards such as fire.
- b. High voltage warning signs shall be displayed in conspicuous locations. Flashing warning lights shall be used to indicate that tests are in progress.
- c. Shorting switches and grounding devices that normally discharge the capacitor bank shall be clearly visible to the test operator. These devices shall be fail-safe and shall function to a safe configuration with no electrical power.
- d. A voltmeter connected across the capacitor bank shall be clearly visible to the test operator at all times. A redundant voltmeter shall be installed at the capacitor bank.
- e. Prior to touching a high voltage component within the test area, personnel shall determine, by using a grounding wand approved by the safety manager for the particular installation, that the capacitor bank is fully discharged to a building ground.
- f. Extreme caution shall be used on capacitor banks that are operated by dc voltages, since a dc capacitor bank will maintain a residual voltage for extended periods.
- g. Capacitors that are connected in series/parallel to form a bank shall be treated with great care, and each capacitor terminal in a series/parallel string shall be properly shorted to ground prior to making any changes to a test bank or circuit.

8.12 BIBLIOGRAPHY

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- ANSI/IEEE 516-1995. IEEE Guide for Maintenance Methods on Energized Power Lines.
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- Public Law 91-596, Sec. 19. 1970. Occupational Safety and Health Act (OSHA), 1970. Federal Agency Safety Programs and Responsibilities.
- Title 29, Code of Federal Regulations, Pt. 1910,
 - ≡ Sec. 132. Occupational Safety and Health Standards. General Requirements
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APPENDIX A

WARNING - HAZARDOUS AREA

BUILDING _____ ROOM _____ IS CLASSIFIED AS A
HAZARDOUS AREA, PER NFPA STANDARDS, WITH THE
CONCURRENCE OF THE GLENN SAFETY OFFICE AS OF ____/____/____.

THE ELECTRICAL INSTALLATION IN THIS AREA IS RATED FOR
CLASS _____ DIVISION _____ GROUP _____ PER NFPA 70-19
NO MODIFICATIONS MAY BE MADE TO THIS AREA WITHOUT
WRITTEN APPROVAL.

THE GLENN OPERATING ORGANIZATION RESPONSIBLE FOR THIS
AREA IS _____ - PABX _____.

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